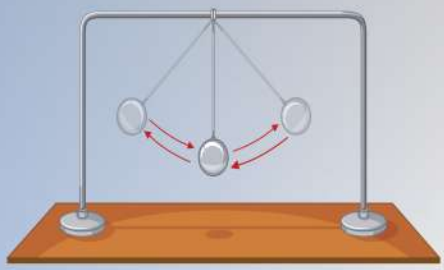
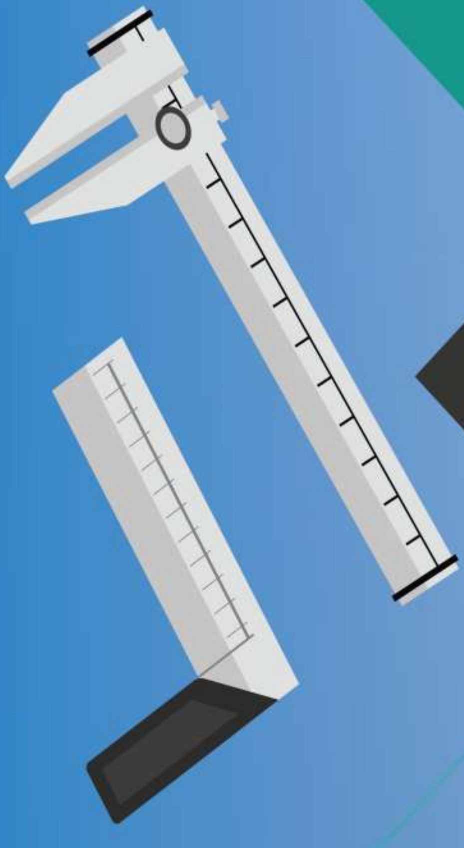
ما كان لله دام و اتصل
و ما كان لغيره انقطع و انفصل

بسواعدنا نبنيها





المانيوال الجديد لمختبر الفيزياء ١

Faculty of Engineering Technology

Physics and Basic Sciences Department

General Physics Laboratory I

Prepared by Physics Staff

Course Number: 30201111

Experiment #1: Introduction: Significant Figures & Errors

Student Name:……………………………………………..

Student Number:…………………………………………

Submission Date: ……………………………………………..

Experiment Title: Introduction: Significant Figures & Errors

No measurement made is ever exact. The **accuracy** (correctness) and **precision** (number of significant figures) of a measurement are always limited by the apparatus used, by the skill of the observer, and by the basic physics in the experiment. In doing experiments we are trying to establish the best values for certain quantities. We must also give a **true values** based on our limited number of measurements.

The **significant figures** (also known as the **significant digits** and **decimal places**) of a number are digits that carry meaning contributing to its measurement resolution (**Accuracy** and **precision**).

The use of significant figures allow a much quicker method to get results that are approximately correct even when we have no uncertainty values.

1-1) Identifying significant digits:

To identify the significant digits we use the following rules:

- A significant figure is any digit from 1 to 9 and any zero which is not a place holder.

Example: 123.45 have five significant figures, and 132.0 have four significant figures since the last zero is not a place holder, and the same thing for 9.070 which has four significant figures.

- Leading zeros are never significant: For example, in a numbers like 0.000515 and 0.00320 there are 3 significant figures, where the first zeros are just place holders.

However, some times in a number that does not have a decimal point an ambiguity that arises with zeros. That is when do we need to use zero as a place holder or as a significant figure?

Various conventions exist to address this issue:

➢ An over line, sometimes also called an over bar, may be placed over the last significant figure; any trailing zeros following this are insignificant. For example, $13\bar{0}0$ has three significant figures (and hence indicates that the number is precise to the nearest ten).

➢ A decimal point may be placed after the number; for example "100." indicates specifically that three significant figures are meant.

➢ Using **scientific notation** ($a \times 10^b$), Suppose we measure a length to three significant figures as 8000 cm. Written this way we cannot tell if there are 1, 2, 3, or 4 significant figures. To make the number of significant figures apparent we use **scientific notation**, 8×10^3 cm (which has one significant figure), or 8.00×10^3 cm (which has three significant figures), or whatever is correct under the circumstances.

An effective method for determining the number of significant figures is to convert the measured or calculated value to scientific notation because any zero used as a placeholder is eliminated in the conversion.

Rounding off answers in regular and scientific notation.

Some time we need to approximate an answer which has a lot of digits to an appropriate number of significant figures. That is mean we have to use the rounded off rules and start the rounding form the last digit as the following:

❖ If the digit is greater than 5 we add 1 to the left digit.

❖ If the digit is less than 5 we leave the left digit as it is.

❖ If the digit is equal to 5 then:

  ○ If the left digit is odd we add 1.

  ○ If the left digit is even we leave it as it's.

Examples: round of the following numbers to three significant figures:

11.274637	→	11.3
113853.3	→	$11\bar{4}000$ or 11.4×10^4
0.00267546	→	0.00268 or 2.68×10^{-3}

1-2) Objectives:

a) To learn how to produce an accurate, complete and clear record of measured quantities.

b) To learn how to deal with errors and significant figures to get best accurate results.

c) To demonstrate the importance of estimating uncertainties in measurements.

d) To know how to determine the precision of the final result from primary measured quantities.

e) To learn how to represent and plot (x-y) data in a graph.

f) To learn how to draw conclusions from different types of plotted graphs.

1-3) **Handling significant figures in calculations follow two major rules**:

1-2-1) For addition and subtraction:

When adding or subtracting using significant figures rules, results are rounded to the position of the least decimal places of any term being summed (or subtracted).

***Examples*:**

47.324 + 22.61 = 69.93 (not (69.934)

3.45 + 12.5 = 16.0 (not 15.95)

123.6 – 12.657= 110.9 (not 110.943)

25.054 – 12.5 = 12.6 (not 12.554)

1-2-2) For multiplication and division:

When multiplying or dividing numbers, the result is rounded to the *number* of significant figures in the factor with the least significant figures

***Examples*:**

$3.8 \times 22.7 = 86.$ (not 82.42)

$123.4 \times 45.9 = 56\bar{6}0$ or 5.66×10^3 (not 5664.06)

$54.5/2.3 = 24.$ (not 23.695652173913043….)

$4.33/365.25 = 0.0119$ (not 0.011854893….)

- **Uncertainties and Error Propagation**

It is not possible to perform an absolute measurement. We use the synonymous terms **<u>uncertainty</u>, <u>error</u>, or <u>deviation</u>** to represent the variation in measured data, there are three causes of uncertainty or error of measurements: *human*, *instrumental*, and *statistical*. The human uncertainty depends on the skills of the person performing the measurement. The instrumental uncertainty usually depends on the smallest value which can be measured with the instrument as described by the scale of the instrument (digital or analog).

The instrumental uncertainty, □x, will be the half of the smallest division in the scale of the analog measurement device, and it will be the smallest division if the device was digital.

The measured value x must equal those of the corresponding uncertainty Δx. Some examples of correctly written measurement are given as:

$$(L \pm \Delta L) = (2.006 \pm 0.005)\ \text{m}$$

$$(m \pm \Delta m) = (63.7 \pm 0.4)\ \text{kg.}$$

That mean that the number of decimal places of the measured value and its corresponding uncertainty must agree.

Propagation of Errors, Basic Rules

Suppose two **measured** quantities x and y have uncertainties, □x and □y: we would report (x ± □x), and (y ± □y). From the **measured** quantities a new quantity, z, is **calculated** from x and y. What is the **calculated** uncertainty, □z, in the **calculated** z?

The quantity □z is called the **<u>absolute error</u>** or the **<u>uncertainty</u>** while □z/z is called the **<u>relative error</u>** or the **<u>precision</u>**. **Percentage error** is the fractional error multiplied by 100%. In practice, either the percentage error or the absolute error may be provided. Thus in machining an engine part the **tolerance** is usually given as an absolute error, while electronic components are usually given with a percentage tolerance.

In this course we will use a simplified version of the proper statistical treatment. The examples included in this section also will include the proper procedures of rounding of answers.

(a) Addition and Subtraction: z = x + y or z = x - y

We will assume that you have measured values for the quantities *x* and *y*, with uncertainties Δx and Δy. The final result of z is the sum or difference of these quantities and the uncertainty Δz can be found by the following:

$$\Delta z = |\Delta x| + |\Delta y|$$

Again for both cases the addition and subtraction, and if we have another relation like $z = u + v - w$, with an uncertainties Δu, Δv, Δw, then

By absolute error $\Delta z = |\Delta u| + |\Delta v| + |\Delta w|$.

In all of the above cases **the relative error** and **the percentage error** are given by:

$$R.E. = \frac{\Delta z}{z}$$

$$P.R.E = \frac{\Delta z}{z} \times 100\%$$

Example:

An object starts its motion from the position $x = (4.2 \pm 0.3)m$ and ends with the position $y = (16.2 \pm 0.4)m$, then the displacement $z = y - x = 16.4 - 4.3 = 12.1m$, and the uncertainty:

$\Delta z = |0.4| + |0.3| = 0.7m$, using absolute error, which gives a final result: $z = (12.1 \pm 0.7)m$.

(b) Multiplication and Division: z = x y or z = x/y

For the multiplication of two quantities the uncertainty in the final result is found by summing the precisions of the original measurements and then multiplying that sum by the product of the measurement values.

So if z = $x \times y$, or $z = x / y$, then in both cases:

$$\Delta z/z=\Delta x/x + \Delta y/y.$$

Examples (multiplication and division):

(I) Determine the area of a rectangular sheet with length l= (2.60 ± 0.03) m and width w= (0.80 ± 0.02) m.

Solution:

$$(l \pm \Delta l) = (2.50 \pm 0.03)$$

$$(w \pm \Delta w) = (0.80 \pm 0.02)$$

$$A = l*w = 2.0 \text{ m}^2$$

$$\Delta A/A = \Delta l/l + \Delta w/w$$

$$\Delta A/2.0 = 0.03/2.50 + 0.02/0.80 = 0.012 + 0.025 = 0.037$$

$$\Delta A=0.07,$$

The area ($A \pm \Delta A$) = (2.0 ± 0.07) m^2.

(II) If $w = (4.52 \pm 0.02)\ cm$, $x = (2.0 \pm 0.2)\ cm$. Find $z = w\,x$ and its uncertainty.

$z = w\,x = (4.52)\,(2.0) = 9.04\ cm^2$

$$\frac{\Delta z}{9.04} = \frac{0.02}{4.52} + \frac{0.2}{2.0} = 0.1044.\ \ So\ \ \Delta z = 0.1044 * 9.04 = 0.944$$

$$z = (9.0 \pm 0.9)cm^2$$

The uncertainty is rounded to one significant figure and the result is rounded to match.

(III) Find the average speed v if distance is $x = (\,2.0 \pm 0.2)\ cm$, and the time $t = (3.0 \pm 0.6)\ sec$.

$$v = \frac{x}{t} = \frac{2.0}{3.0} = 0.6667 cm/s\ ,\ \ \Delta v = (0.6667) * (\frac{0.2}{2.0} + \frac{0.6}{3.0}) = 0.2 cm/s$$

Then $v = (0.7 \pm 0.2)\ cm/sec$

(c) Products of powers: $z = x^m y^n$

The results in this case are taking the form

$$\frac{\Delta z}{z} = |m|\frac{\Delta x}{x} + |n|\frac{\Delta y}{y}$$

(IV) Example: *w = (4.52 ± 0.02) cm, A = (2.0 ± 0.2) cm², y = (3.0 ± 0.6) cm*. Find $wy^2/\sqrt{A}$

$$z = \frac{wy^2}{\sqrt{A}} = \frac{4.5*(3.02)^2}{\sqrt{2.0}} = 28.638\,cm^2$$

$$\frac{\Delta z}{28.638} = \frac{0.2}{4.5} + 2*\frac{0.6}{3.0} + (\frac{1}{2})*\frac{0.2}{2.0} = 0.49$$

The second relative error, (□y/y), is multiplied by 2 because the power of y is 2.

The third relative error, (□A/A), is multiplied by 0.5 since a square root is a power of one half.

So □*z = 0.49 (28.638 cm²) = 14.03 cm²* which we round to 14. *cm²*, finally *z = (29. ± 14.) cm²*.

1-4) Statistical Uncertainty-Mean standard deviation and standard error of the mean (SEM):

For a repeated measurement that experiences random uncertainties. Statistical treatments give the most likely uncertainties; a statistical mean value is a simple average for a set of repeated measurements. For N repetitions of a measurement x_i, the statistical mean is written as:

$x = 1/N\,[x_1 + x_2 + x_3 + \ldots + x_N]$, or average value of x is

$$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N}$$

To know the uncertainty in the measurements (how much deviated from the mean value) we have to calculate the standard deviation (σ). To determine the standard deviation, first the mean value x must be calculated, then σ is calculated by taking the sum of the squares of deviations of each point from the mean and dividing that sum by N-1 as given by:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(\bar{x} - x_i)^2}{N-1}}$$

The acceptable value for x is given by:

$$x = \bar{x} \pm \sigma$$

How to Draw Graphs:

Graphs are a means of summarizing data so that the results may be easily understood. A good graphs are done on fine grid graph paper so that data may be easily read from the graph, otherwise, any new data may be hard to extracted from the graph.

A sample graph is shown in Fig. 1. When you draw a graph, pay attention to the following rules:

- The graphs *must be* drawn in *pencil*.
- The graphs must be drawn on graph paper.
- All graphs starts with a title specify what quantities has been drawon. For example:

" *Motion with constant acceleration*"

"*Height vs. Time*".

- Find a suitable scale for your data, (1 cm → 10 meters) , (1 cm → 1 second). The scale should be chosen so that it is ***easy to read***.
- When drawing a graph of "Hight" versus "Time", put "Hight" on the vertical axis and "Time" on the horizontal.
- Use as much of the page space as possible as long as it is simple. Making a complicated graph doesn't add anything to the final product.
- Label the axes of the graph. In Fig.1, the x-axis indicates time measured in seconds, then the lable should read "Time (s)".

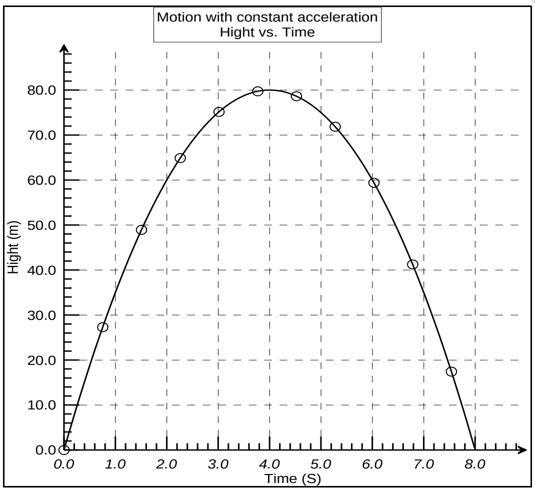


Figure 1: Drawing a graph to represent the data in x-y relation

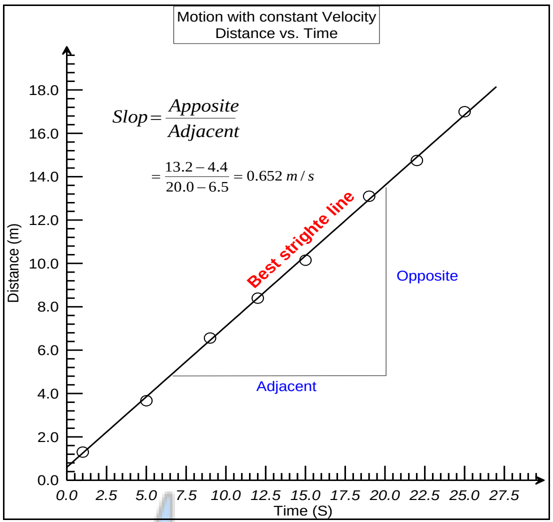


Figure 2: Drawing best line and calculating the slope

When you are asked to draw a smooth curve passing through your data, the curve generally will not pass through all the data points, since there is always a small amount of errors in any measurement.

If the graph is a straight line, then often we want to find the slope of the graph. The slope of a straight line is found by drawing a triangle like the one shown in Fig. 2, and determining the ***Opposite*** (the length of the triangle in the y-direction) and the ***Adjacent*** (the length of the triangle in the x-direction). The slope is then given by

$$slop = \frac{Oppsite}{Adjacent}$$

Notice that if the curve goes down, then the ***Opposite*** is negative and the slope is negative. Notice also that the units of the slope are given by the units of the y-axis over the units of the x-axis. If the y-axis is *meters*, and the x-axis is *seconds*, then the slope of a line on the graph is in *m/s*. Finally, remember to show your calculations on the graph, as done in Fig. 1.

Problems:

(a) Find the average and the average deviation of the following measurements of a mass.

4.32, 4.35, 4.31, 4.36, 4.37, 4.34 grams.

(b) Express the following results in proper rounded form, x ± □x.

(i) m = 14.34506 grams, □m = 0.04251 grams.
(ii) t = 0.02346 sec, □t = 1.623 x10^{-3} *sec.*
(iii) M = 7.35 x 10^{20}*kg □M = 2.6 x* 10^{20} *kg.*
(iv) m = 9.11 x 10^{-33} *kg □m = 2.2345 x* 10^{-33} *kg*

(c) Are the following numbers equal within the expected range of values?

(i) (3.42 ± 0.04) m/s and 3.48 m/s?
(ii) (13.106 ± 0.014) grams and 13.206 grams?
(iii) (2.95 ± 0.03) x 10^{-8} *m/s and 3.00 x* 10^{8} *m/s*

(d) Calculate z and □z for each of the following cases.

(i) z = (x - 2.5 y + w) for x = (4.72 ± 0.12) m, y = (4.4 ± 0.2) m, w = (15.63 ± 0.16) m.
(ii) z = (w x/y) for w = (14.42 ± 0.03) m/s^2*, x = (3.61 ± 0.18) m, y = (650 ± 20) m/s.*
(iii) z = x^3 *for x = (3.55 ± 0.15) m.*
(iv) z= v (xy+w) with v= (0.644 ±0.004) m, x= (3.42 ±0.06) m, y= (5.00 ±0.12) m, w= (12.13 ± 0.08)m^2*.*

(e) How many significant figures are there in each of the following?

(i) *0.00042 (ii) 0.14700 (ii) 4.2 x* 10^{6} *(iv) -154.090 x* 10^{-27}

(f) I measure a length with a meter stick which has a least count of 1 mm I measure the length 5 times with results in mm of 123, 123, 124, 123, 123 mm. What is the average length and the uncertainty in length?

(g) Graph: A student has made the following measurements for the sides of 6 cubes of some material with different volumes and its masses and tabulated the results in the following table.

(i) Use the table to find the volume and calculate the average mass density (□=*m/V*) of the material and its uncertainty.

(ii) Use the relation (□=*m/V*) to draw a suitable graph *V* vs. *m* on clean graph paper to find the mass density □ from the slop.

side length *l(cm)* $\Delta l=0.05cm$	*mass* *m(g)* $\Delta m=0.05g$	*volume* $V(cm^3)$	ΔV
3.3	258.4		
4.8	728.0		
6.2	1675.6		
8.7	4515.8		
9.5	5743.2		

Experiment #2: Measurements

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ……………………………………..

Experiment Title: Measurements

Objectives:

To study the Vernier scale principle and to learn the use of Vernier callipers for the accurate measurement of length. To become familiar with the use of micrometer callipers for the accurate measurement of small lengths.

Experiment duration: 3hours

Apparatus:

Ruler, vernier calliper, micrometer, and forms.

Introduction:

Careful quantitative measurements are very important for development of physics, the most exact of the experimental sciences. The measurement of length is basic to many of the experiments performed by physicists.

Theory:

- **For vernier caliper**

Length scale is one of the oldest necessities. For this reason, the simplest methods of length measurement are known very well. For instance, the narrow side of vernier is used for minor lengths. This side of vernier has a milimetic ruler and an edge which is perpendicular to the ruler. Furthermore, there is a second measurement edge which is fitted to the ruler. Zeros of the both scales should coinside if both scales contact each other.

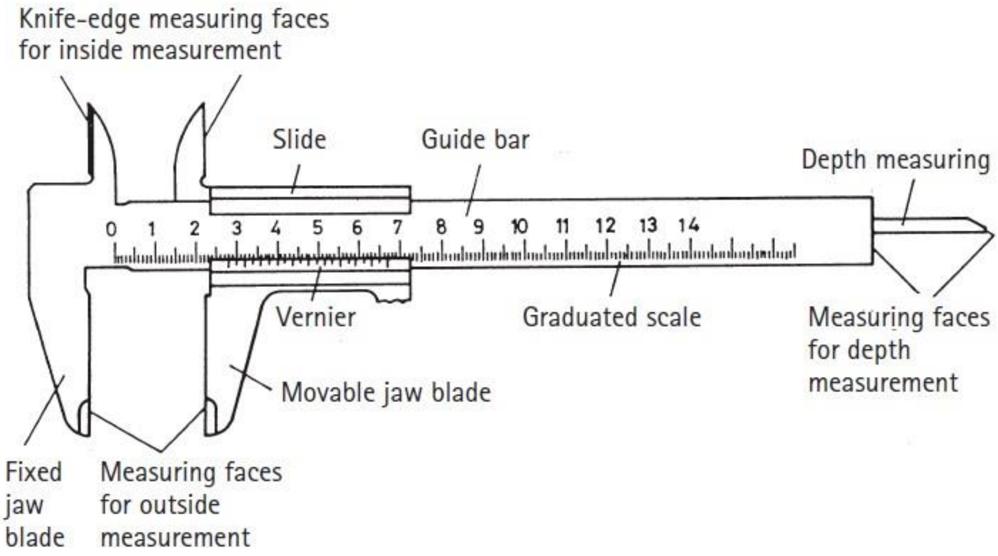


Figure 1: Vernier Calliper

This device can measure both inside and outside dimensions down to 0.01cm (don’t use the top scale which measures in inches). Close the caliper gently on some test object to get an outer dimension reading, or expand the horns of the caliper into some cavity for an interior reading. See picture below:.

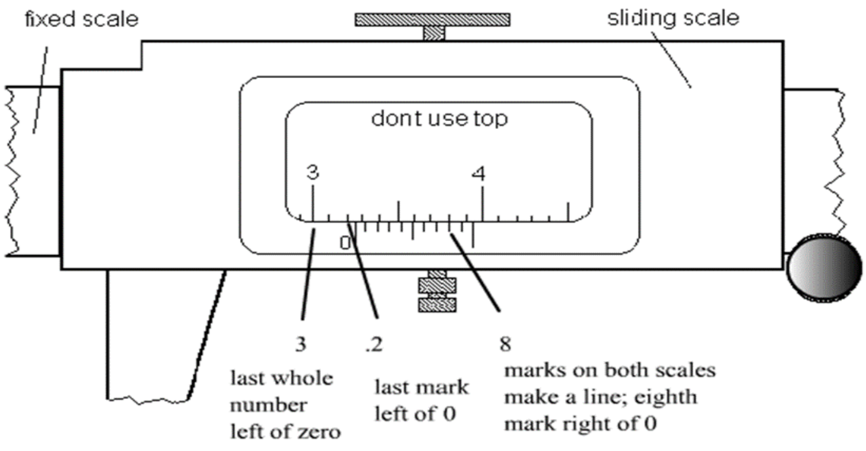


Figure 1.2

The centimetre reading is taken by finding the first whole digit (as on a meter stick) on the fixed scale to the left of the zero mark on the sliding scale, 3 in the figure. The next number, the first decimal place, also comes from the fixed scale: it is the last small ‘‘hash’’ mark to the left of the zero, 0.2 in our case. It is the last number, the second decimal place, that is most difficult to establish. Find where a hash mark on the sliding scale makes a straight line with a similar mark on the fixed scale, 0.08 in the figure on the sliding scale. (This is the vernier

quality of the calliper, and you will see other vernier style measuring devices in later labs.) Now add 3cm+ 0.2cm + 0.08cm for your reading ,it will be like this 3.28 cm .

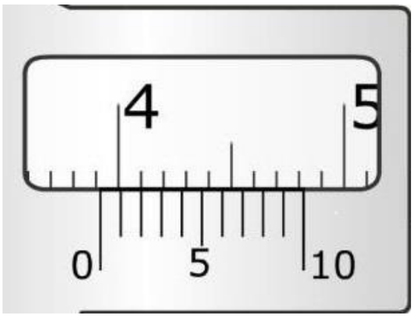


Figure 1.3: The value on fixed scale 3.9 cm, 0.02 in the sliding scale so the reading is 3.92cm

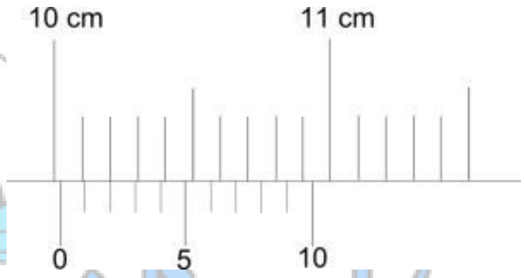


Figure 1.4: The value on fixed scale 10.0 cm, 0.02 in the sliding scale so the reading is 10.02cm

- **For micrometer**

Thin thicknesses are measured by micrometer. Micrometer consists of fixed heavy piece on left and maneuverable piece (the ratchet) on right. (Figure 1.4) The ratchet is turned clockwise until the object is ‘trapped’ between these two surfaces.
Each revolution of the ratchet moves the spindle face 0.5mm towards the anvil face. When measurement mouth is closed, micrometer shows zero. Some micrometers are provided with a vernier scale on the sleeve in addition to the regular graduations in order to increase accuracy. This vernier scale has 50 lines and each line equals 10 micrometer. Thus, the accuracy of measurement is 2 micrometer (Figure 1.5).
The ratchet is used to conduct measurement in order for the specimen doesn’t get damage.

Figure 1.4 : Micrometer
a: Anvil face

Figure 1.5: c represents a distance on rough scale, d represents a

b: Spindle face

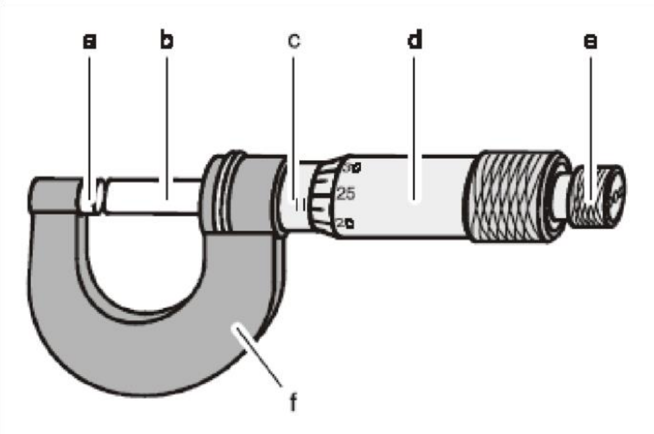
c: Sleeve with rough scale

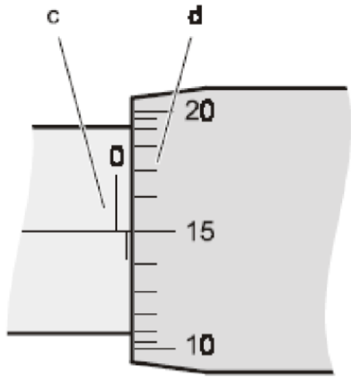
d: Thimble with vernier scale

e: The ratchet

distance on vernier scale

d=0,5mm+0,150mm=0,650mm





f: Frame

Example:

Figure 1.6: 5.0 mm + 0.0 mm = 5.0mm

Figure 1.7: 5.5mm +0.0 mm = 5.5 mm

Figure 1.6: 5.0 mm + 0.35 mm = 5.35mm

Figure 1.7: 5.5mm +0.40 mm = 5.9 mm

Procedure:

Procedure (1): Lab Table

If the dimensions of the object being measured are much larger than the precision of the measuring instrument (100 times or more), the instrument is considered very adequate for the measurement and will give fairly "precise" results.

1. Using a meter stick, measure the length and the width of the lab table andrecord them in meters. This reading should have five significant figures, the last digit being a fraction of a millimeter (which is an estimate). Record your data in data table (1) in units of meters (m) in column (2), centimeters (cm) in column (3) and millimeters (mm) in column (4). Use scientific notation any time the data or the calculation is larger than 1000.

2. Calculate the area of the table top in m^2, cm^2 and mm^2 and enter it in the data table. Remember the units. When you multiply the numbers, you also must multiply the units.

Procedure (2): Rectangular Block

1. Using a ruler, measure the dimensions of the rectangular block in cm andrecord your measurement in data table (2), column (3). The precision of the ruler is a half a millimeter (0.5 mm), the same as the meter stick.

2. Convert the dimensions to m in column (2) and mm in column (4).

3. Calculate the surface area of the block $A = 2LW + 2LH + 2WH$ and enter it in your data table in m^2, cm^2 and mm^2. Note: 1 cm = 0.01 m = 1×10^{-2} m and 1 mm = 0.001 m = 1×10^{-3} m.

4. Calculate the volume of the block, $V = LWH$, and enter it in your data table. Remember the units!

5. Using a digital scale (or triple beam balance), measure the mass of the blockand record it in column (3) in grams (g) and in column (2) in kilograms (kg). 1 g = 0.001 kg.

6. Calculate the density of the block of wood $\rho = M/V$ in (kg/m^3) (column 2) and (g/cm^3) (column (3).

Procedure (3): Cylindrical Block

1. Here we will repeat procedure (2) using a cylindrical block instead of rectangular and using a vernier caliper instead of the ruler. The precision of the caliper is 0.005 mm which is 100 times smaller than the precision of the ruler which is 0.5 mm.

2. Using a vernier caliper, measure the diameter and the height of the cylindrical block and record them in (mm) in column (4), in (cm) in column (3) and in (m) in column (2).

3. Calculate the surface area (including the top and the bottom) and the volumeof the block. $A = 2(\pi r^2) + 2\pi rH$ and $V = \pi r^2 H$. Remember the units!

4. Measure the mass of the cylindrical block and calculate its density as you didwith the rectangular block. Enter the values in the data table.

5. Inspect the measurements and calculations of the last two procedures andmake a comment on the improved precision in the latter procedure.

Data:

1. Do all the calculations required to fill in the data tables. Make sure you round off your answers to the proper number of significant figures and give the units of all measured and calculated quantities.

Data Table (1): Lab Table			
Length, L			
Width, W			
Area, A			
Data Table (2): Rectangular Block			
Length, L			
Width, W			
Height, H			
Surface Area, A			
Volume, V			
Mass, M			
Density, ρ			

Data Table (3): Cylindrical Block			
Diameter, d			
Radius, $r = d/2$			
Height, H			
Surface Area, A			
Volume, V			
Mass, M			
Density, ρ			

Calculations:

Show sample calculation, for example, the complete calculation for Surface Area.

Results:

Provide the error formula used as well as the calculation of the errors of Area and volume and density in in the previous table.

Discussion:

Provide a discussion if necessary.

Conclusion:

Experiment #3: Vectors

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: Vectors

Objectives:

The objective of this lab is add vectors using both the tail-to-head method and the component method and to verify the results using a force table.

Experiment duration: 3 hours

Apparatus:

Force table, protractor, ruler, masses, mass holders, and graph paper.

Introduction and theory:

A scalar quantity is a number that has only a magnitude. When scalar quantities are added together (e.g., prices), the result is a sum.

Vectors are quantities that have both magnitude and direction; specific methods of addition are required. When vector quantities are added, the result is a **resultant**.

A negative vector has the same length as the corresponding positive vector, but with the opposite direction. Making a vector negative can be accomplished either by changing the sign of the magnitude or by simply adjusting the direction by 180°.

$\vec{\mathbf{V}} = 5\ \mathrm{N}\ \ 100$ $\quad$ -$\vec{\mathbf{V}} = -5\ \mathrm{N}\ \ 100$

or

-$\vec{\mathbf{V}} = 5\ \mathrm{N}\ \ 280$

Tail-to-Head Method

Vectors can be added together graphically by drawing them end-to-end. A vector can be moved to any location; so long as its magnitude and drientation are not changed, it remains the same vector. When adding vectors, the order in which the vectors are added does not change the resultant.

- Draw each vector on a coordinate system; begin each from the origin.
- Choose any vector drawn to be the first vector.
- Choose a second vector and redraw it, beginning from the end of the first.
- Repeat, adding as many vectors as are desired to the end of the “train” of vectors.
- The resultant is a vector that begins at the origin and ends at the tip of the last vector drawn. It is the shortest distance between the beginning and the end of the path created.

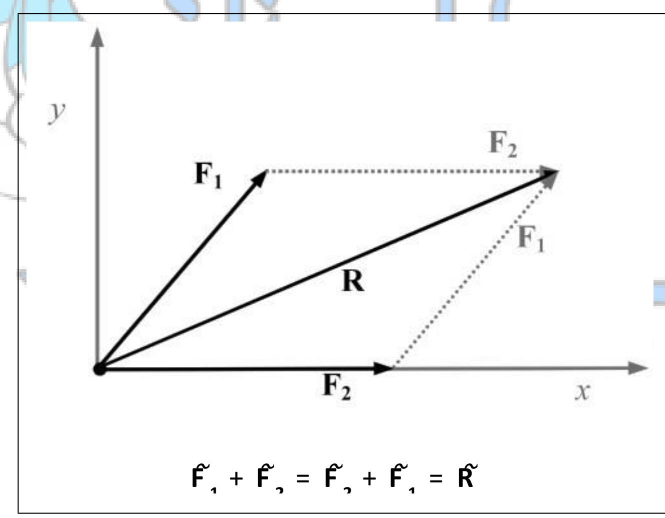


Figure 1: Adding 2 Vectors, Tail-to-Head

The tail-to-head method is often useful when working problems. A quick sketch, rather than measurements, can help verify your solutions.

Component Method

To add vectors by components, calculate how far each vector extends in each dimension. The lengths of the *x*- and *y-components* of a vector depend on the length of the vector and the sine or cosine of its direction:

$$sin\theta = \frac{F_{1_y}}{F_1} \qquad cos\theta = \frac{F_{1_x}}{F_1}$$

Use algebra to solve for each component, $F1_x$ and $F1_y$, from these equations.

$$F_{1_x} = |\vec{\mathbf{F}}_\mathbf{1}|cos\theta$$

$$F_{1_y} = |\vec{\mathbf{F}}_\mathbf{1}|sin\theta$$

$$\theta = tan^{-1}\left(\frac{F_{1_y}}{F_{1_x}}\right)$$

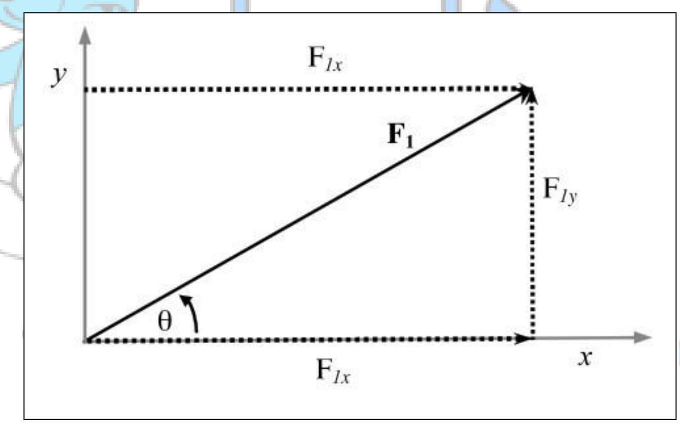


Figure 2

When each vector is broken into components, add the *x-components* of each vector:

$$\sum_{i=1}^{n} F_{i_x} = R_x$$

Then add all of the *y-components*:

$$\sum_{i=1}^{n} F_{iy} = R_y$$

The sums are the *x*- and *y-components* of the resultant vector, **R**

The components of **R** can be converted back into polar form (R, Θ) using the Pythagorean Theorem and the tangent formula

$$|\vec{\mathbf{R}}| = R = \sqrt{R_x^2 + R_y^2}$$

$$\theta = tan^{-1}\left(\frac{R_y}{R_x}\right)$$

Note: Verify the quadrant! A calculator will return only one of two possible angles (Eq. 7). To verify the quadrant, determine if R_x, R_y are positive or negative. If your calculation puts the resultant in quadrant I, but R_x and R_y are both negative, it must be in quadrant III; simply add 180 to the angle.

Force Table Verification

We will use a *force table* to verify our results of vector addition and gain a hands-on perspective. The force table is a circular steel disc with angles 0° to 360° inscribed on the edge (Figure 3).

As noted above, when adding vectors, a resultant vector is determined. To balance the force table, however, a force that is equal in magnitude but opposite in direction must be used. This force is the **equilibrant**, **E**

$$\vec{E} = -\vec{R}.$$

For example, when a 10.0 N force at 0° and a 10.0 N force at 90° are added, the resultant force has a magnitude of 14.1 N at 45°. The equilibrant force has the same magnitude, but the direction is 180° +45° = 225°. The equilibrant must be used to balance the two 10.0 N forces.

Experiment set-up:

Figure 3

Procedure:

Three vectors A, B, and C are given in Table 1 under the "Data" section.

The purpose is use a ruler and a protractor and applies the polygon method to find Resultants R_1, R_2, and R_3 (one at a time) as shown below:

$R_1 = A + B$	$R_2 = A + B + C$	$R_3 = A + B - C$

For each of R_1, R_2, and R_3 take the following steps:

1) Choose a reasonable scale that gives you a drawing big enough for precision measurement and at the same time small enough to where the drawing does not go out of page. Indicate the selected scale on the drawing. For the given vectors in Table 1, if your x-axis is 1 inch above the lower edge of the paper and your y-axis is also 1 inch from the left edge of the paper, none of R_1, R_2, and R_3 will go out of the page provided that you choose your scale as 1cm = 2N.

2) Add the vectors by the polygon method to find each resultant. Record the magnitude and direction of the resultant (that you measure by the ruler-protractor set) in the Table 2 shown below. These are your measured values.

3) Solve for the same resultant that you found in Step 2, but this time by using the analytical method (by calculation and use of trigonometry). Calculate the magnitude and direction of the resultant and record it under calculated (accepted) values in Table 2.

4) Calculate a % error on magnitude and a % error on direction and record them in the space provided in Table 2.

Data:

Table 1

Vector	Magnitude	Direction
A		
B		
C		

Table 2

Resultant	Measured		Calculated (Accepted)		%error on Magnitude	%error on Direction
	Magnitude (N)	Direction (°)	Magnitude (N)	Direction (°)		

R1 = A+ B						
R2 = A+ B+C						
R3 = A+B -C						

Calculations:

Show calculation for R_1, $R_{2,}$ and $R_{3.}$

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Comparison of the results:

Show calculation for %errors

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……………….

Discussion:

Conclusion:

Experiment #4: Newton's second law

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: Newton's second law

- **Objectives:**

1) Proof experimentally that the relation between the net force and acceleration is directly proportional. (When the total mass is constant).

2) Proof experimentally that the relation between the acceleration and the total mass is inversely proportional.(when the net force is constant)

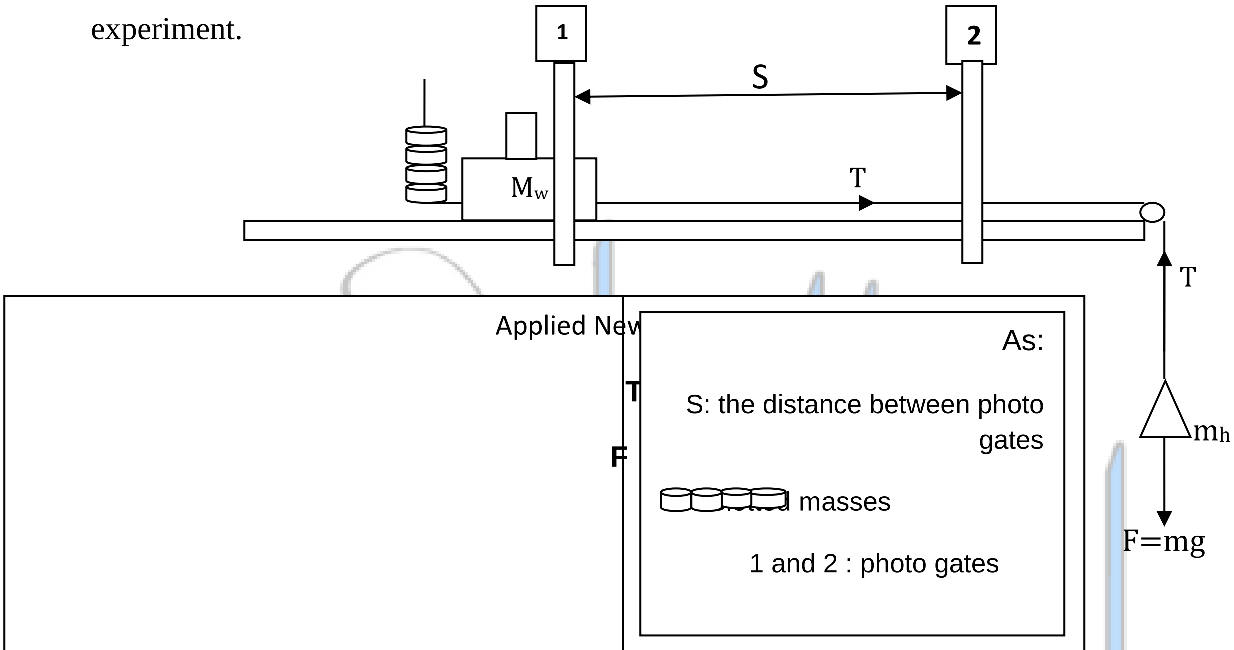
- **Apparatus:**
- Air track, blower, two photogate, masses, glider, hanger, digital counter, and cables.
- **Experiment Duration: (3 hours).**
- ***Introduction*:**

  When looking at the moving objects in our daily life, we notice that some of these objects, when affected by net force, Acquire a negative or positive acceleration, and this acceleration increases when increased the net force, of course, if the mass does not change.

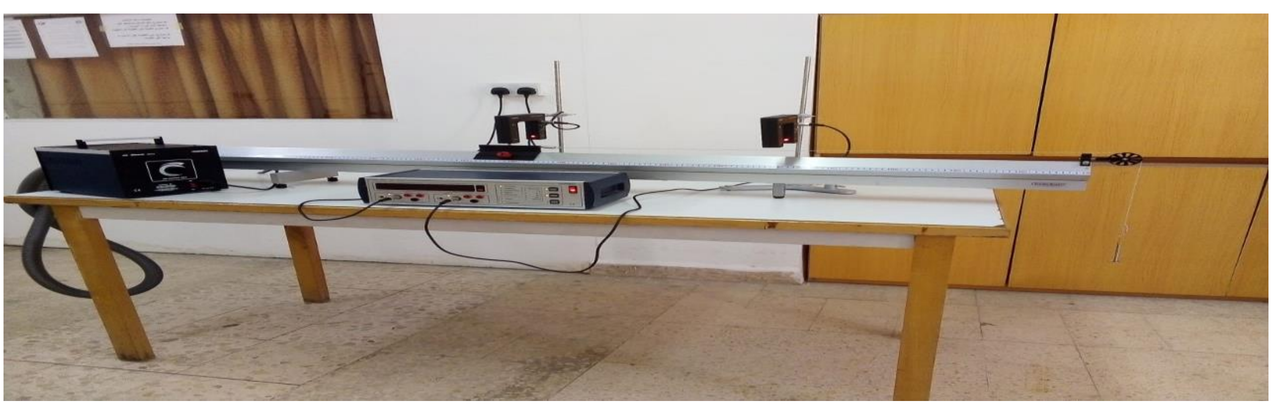
  And the acceleration of these bodies decreased with increasing mass, of course when the net force acting is constant.

- ***Theory*:**

The equation (F= ma),can't be useful in our experiment ,cause there is two masses moving in our experiment not one .so we must drive an equation to achieve the Objectives in the experiment.



- **Experiment set up:**



Setup Picture

- **Procedure:**

The acceleration of the moving cart can be found using equations of motion i.e.

($S=v_o\,t+1/2\,a\,t^2$), as **(v_o=zero)**

$$\mathbf{a=2.S/t^2}$$

While, ($F_{net} = m_h.g$).

Part 1 :(when the total mass is constant):

Note that:-

Fnet	=	M_W+m_h	a
↓		↓	↓
Y		slope	X

As well as you can get different values for (F) by changing (m_h) , by decreasing (Mw) and increasing (m_h), that to keep the total mass is constant.

Data:

M_w+m_h(total mass) =…………..kg , S=……………….m

m_h(kg)	t_1 (s)	t_2 (s)	t_{avareg} (s)	F_{net}(N)	a (m/s^2)

Note that:

$F_{net} = (M_w+m_h)\ a$

$m_h.g= (M_w+m_h)\ .2.S/t^2$

Note that relation between (m_h) and (t) inversely proportional.

- **Discussion and analysis:**

1) Fill the table above .by moving one of the movable masses from (M_w) to (m_h),to keep the total mass is constant, and (F_{net}) will increase in each try.
2) Plot a graph between (F) and (a).
3) Calculate the slope.
4) Determine the physical meaning of the slope.
5) Find the (M_w+m_h) expected value.
6) Find the percentage error for the total mass.

Note that:-

$a = F_{net}.(1/(M_w+m_h))$

Y | slope | X

Part 2: (when the driving force (Fnet)) is constant)

In this part, we will let (mh) constant, so the driving force will be constant.

To get two pairs for plots, we will increase (Mw)

In every attempt, so (a) will change in every attempt.

Data:

$F_{net\ (true\ value)} = m_h.g =$……………………………N

M_w(kg)	(M_w+m_h) (kg)	1/ M_w+m_h(kg^{-1})	t_1 (s)	t_2 (s)	t_{avareg} (s)	a (m/s^2)

- **Discussion and analysis:**
    1) Fill the table above, by increasing (Mw) in each trial.
    2) Plot the relation between (a) and ($1/ M_w+m_h$).
    3) Calculate the slope.
    4) Determine the physical meaning of the slope.
    5) Find the expected value of net force.
    6) Find the percentage error for the net force.

Note that:

$a= F_{net} .(1/(Mw+mh)$

$= F_{net}. 1/ (Mw+mh) . \ 2.S/t^2$

Note that relation between **(M_w)** and **(t)** directly proportional.

Results:

Write down the answers to all questions above in both parts here:

- **Conclusion**

Experiment #5: Gravitational potential energy

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: Gravitational potential energy

Conservation mechanical energy)(

- **Objectives:**

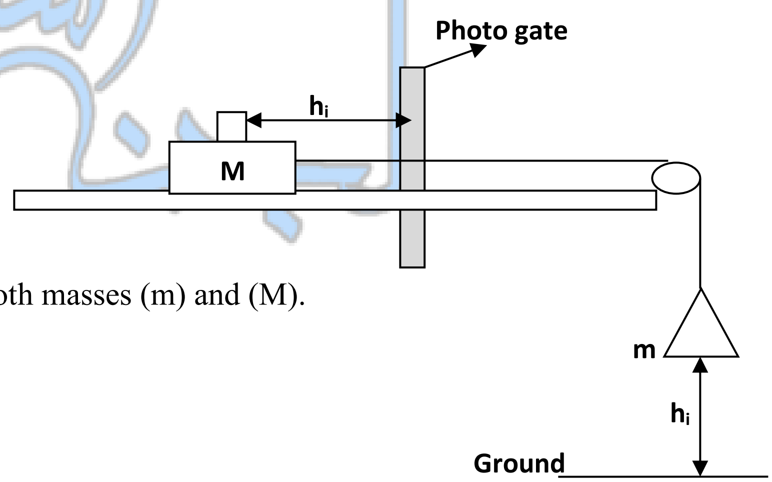
1) Find the acceleration of gravity experimentally. (Fixing (h_i) and change (m)).

2) Find the acceleration of gravity experimentally. (Fixing (m) and change (h_i)).

- **Experiment duration:** (3 hours)
- **Apparatus:**
- Air track, air blower, glider, photogate, digital counter, connection lead, flag, string, pulley, slotted masses, hanger, and balance.
- **Introduction:**
- When letting a ball to fall freely, the ball will descend under the influence of its weight, which is considered conservative force, and since there aren't non-conservative force such as friction, then the (ball-earth) system will be a conservative system.
- In the conservative system, energy doesn't annihilate and doesn't great but rather transforms from one to another, so that the energy in the (ball-earth) system will transform from Gravitational potential energy to kinetic energy.
- **Theory:-**

This system is conservative system

So we can write ($\Delta K + \Delta U_{(g)}$=zero)

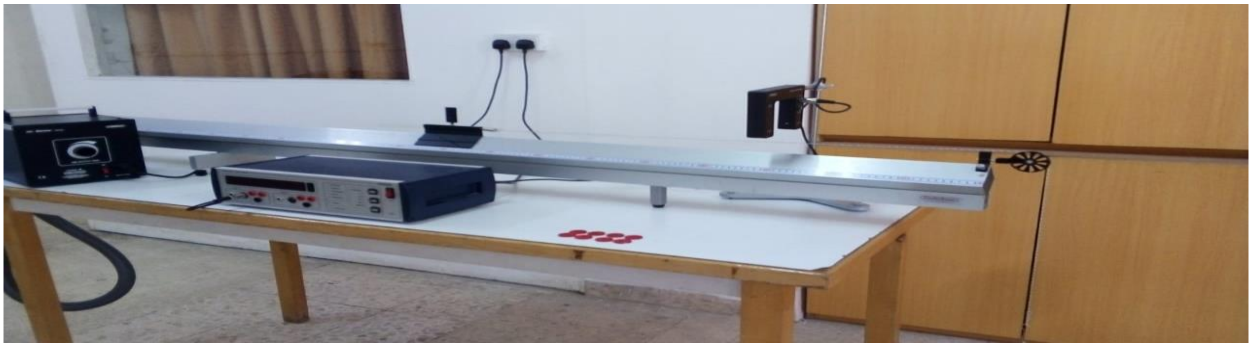


But note that ($\Delta U_{(g)}$) just for (m) and (ΔK) for both masses (m) and (M).

$K_{f(M,m)} - K_{i(M,m)} + U_{f(m)} - U_{i(m)} = \text{zero}$,

but ($K_{i(M,m)}$=zero) and ($U_{f(m)}$=zero)

$$K_{f(M,m)} = U_{i(m)} \Longrightarrow 1/2(M+m)v_f^2 = mgh_i$$



- **Experiment set up:**

Important notes before making the practical part:

1)The location of the photogate must be determined before the practical part is conducted in the two branches of the experiment, where we want it in a place where we can detect final velocity, which will be the same for the two bodies, can be determined because they are connected together by a thread, and the final velocity can be determined when all the energy transformations end, when (m) It reaches the ground, so we place the optical cell in front of (M) when (m) it comes into contact with the ground and the thread is tight.

2) The height (hi) can be determined by returning (M) the distance you want when (m) is touching the ground and the thread is tight and not loose, and therefore (m) will rise above the ground by the same amount (hi).

Part 1) Determining the acceleration due to gravity experimentally. (Fixing (hi) and changing (m)).

- **Data:**

hi=…………….(m),M=……………….(kg), L=……………..(m)

M(kg)	t(s)	V_f=L/t (m/s)	$v_f^2(m^2/s^2)$	$K_{f(M,m)}$ =1/2.(M+m) v_f^2 (J)

- **Discussion and analysis:**

1) Measure (h_i) which you want to fix, record the mass of (M), and record the length of the flag (L).
2) Fill the table below by changing (m) and fixing (h_i).

3) On the graph paper plot ($K_{f(M,m)}$) versus (m)
4) Write the physical meaning of the slope.

Note that:

$$\underbrace{K_{f(m,M)}}_{Y} = \underbrace{g.hi}_{= SLOPE} \; . \; \underbrace{m}_{X}$$

5) Find the slope.
6) Find the acceleration of gravity (g).
7) Find the percentage error in (g).
8) Write down the answers to parts (4-7) in the Results Section below

Results:

Part 2: Find the acceleration of gravity experimentally. (Fixing (m) and changing (h_i)).

- **Data**

L =……………………(m) m=…………….(kg),M=……………..(kg)

h_i (m)	t (s)	V_f=L/t (m/s)	$K_{f(M,m)}$ =1/2(M+m) v_f^2 (J)

- **Discussion and analysis:**

1) Detect (m) which you want to fix, record the mass of (M), and record the length of the flag (L).
2) Fill the table by changing (hi) and fixing (m).
3) On the graph paper plot ($K_{f(M,m)}$) versus (hi).
4) Write the physical meaning of the slope.

Note that:

$$\underbrace{\mathbf{K_{f(m,M)}}}_{Y} = \underbrace{\mathbf{g.m}}_{=\ SLOPE} \ . \ \underbrace{\mathbf{hi}}_{X}$$

5) Find the slope.
6) Find the acceleration of gravity (g).
7) Find the percentage error in (g).
8) Write down the answers to parts (4-7) in the Results Section

Results:

- **Conclusion:**

Experiment #6: ONE-DIMENSIONAL COLLISIONS

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: ONE-DIMENSIONAL COLLISIONS

Objectives:

1) To verify the law of conservation of linear momentum in one-dimensional collisions.
2) To study conservation of energy and linear momentum in both elastic and inelastic one-dimensional collisions.

Experiment Duration: (3 hours)

Apparatus:

Frictionless carts, Frictionless air track, photogate, digital timer, additional mass, air supply.

Introduction:

An important area of application of the conservation laws is the study of the collisions of various physical bodies. In many cases, it is hard to assess how exactly the colliding bodies interact with each other. However, in a closed system, the conservation laws often allow one to obtain the information about many important properties of the collision without going into the complicated details of the collision dynamics. In this lab, we will see in practice how the conservation of momentum and total energy relate various parameters (masses, velocities) of the system independently of the nature of the interaction between the colliding bodies.

Theory:

Conservation of linear momentum is the most important implications of Newton's law. Linear momentum (P) for a particle of mass, m moving with velocity, (v), is defined as

P = mv. The momentum (P) and velocity (v) are both vectors and have the same direction. For a system of n particles with masses m_1, m_2, m_3,….., m_n, with respective velocities v_1, v_2, v_3…, v_n, the linear momentum of the system is the vector sum of the individual momentum, i.e.,

$$P_{sys} = P_1 + P_2 + \ldots + P_n = m_1 v_1 + m_2 v_2 + \ldots + m_n v_n \qquad (1)$$

The kinetic energy of a particle of mass m and velocity v is defined as KE= ½ m v^2. (Note that KE is a scalar quantity). The kinetic energy of the system of (n) particles is given by:

$$KE_{sys} = KE_1 + KE_2 + \ldots + KE_n = \tfrac{1}{2} m_1 v_1^{\,2} + \tfrac{1}{2} m_2 v_2^{\,2} + \ldots\ldots\ldots + \tfrac{1}{2} m_n v_n^{2} \qquad (2)$$

The conservation of linear momentum states that if the net force acting on a system of particles is zero then the linear momentum of the system is conserved (i.e., P_{sys} is constant). In isolated collision problems the net linear momentum before and after the collision must be same

$$P_{sys} \text{ before collision} = P_{sys} \text{ after collision} \qquad (3)$$

For the one dimensional collision problem involving two objects as shown in Figure 1, we can write equation (3) as

$$P_{1i} + P_{2i} = P_{1f} + P_{2f} \qquad (4)$$

Where i, f refer to the initial and final stages. Direction of velocity (or momentum) is taken position when the object is moving to the right as indicated by arrow heads in Figure 1.

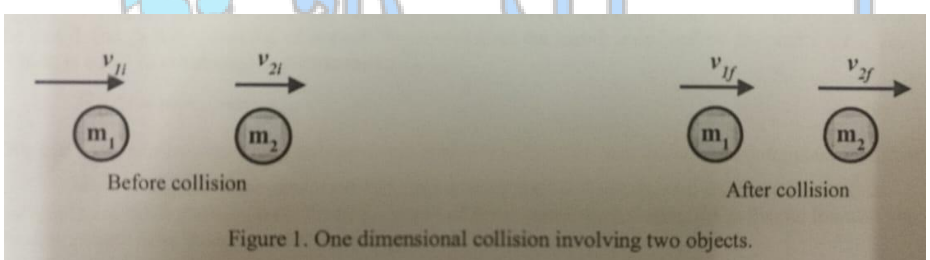


Figure 1. One dimensional collision involving two objects.

In our experiments, we will study the collision of two carts (cart-1 and cart-2) moving on a horizontal track. The carts and the track are designed for negligible friction. Since there are no external forces acting on the carts during the collision, P_{sys} must be conserved. Additionally, we will keep one of the carts (cart-2) at rest before collision for all cases (i.e., $v_{2i} = 0$ hence $P_{2i} = 0$). For this condition, we can simplify equation (4) as

$$m_1 v_{1i} = m_1 v_{1f} + m_2 v_{2f} \qquad (5)$$

By measuring the masses and the velocities before and after the collision, we can easily verify the conservation of linear momentum. In this lab, we will investigate two cases.

Elastic collision

KE_{sys} before collision = KE_{sys} after collision

By definition, in an elastic collision, the KE_{sys} is conserved, i.e.

Perfectly inelastic collision

In the case of a perfectly inelastic collision, the carts stick together after the collision. Thus, both carts will have the same final velocities, that is $v_{1f} = v_{2f} = v_f$.

(Note: The KE_{sys} is not conserved in a perfectly inelastic collision.)

Experiment Set-up:

Procedure:

1) Measure the masses of the carts and additional loads, and record in the data sheet.
2) Plug in the photogate power supply. Switch the photogate settings to: mode: collisions.
3) Check if the track is leveled. You can easily check if the track is leveled or not by placing a cart on the track. If the cart stays at rest even if you move the cart to another spot, it is leveled. If the track is not leveled, the cart starts moving. You should then level it by adjusting the screws under the track.
4) Set the appropriate height of the photogate so that carts with flag can pass freely through the gate and the flag also blocks the light of the photogate .The timer is started when the front edge of the flag passes through the photogate. The timer is then

stopped when the back edge of the flag leaves the photogate. The velocity of cart is, therefore, length of flag divided by the time interval measured by the timer

5) Place cart-2 near the center of the track (between the photogates) and the cart-1 at the edge of the track.
6) Now, get ready to make the collision, by pushing cart 1 using your hand.
7) Record the value of time, masses, L (width of the flag) in the table.
8) You can repeat steps above with different masses adding to the carts.

Data:

A. Elastic collision

L_1=…….. (m) **L_2**=…….. (m)

Before collisions								
	Cart 1	Cart2						
Trial	M_1 (Kg)	M_2 (Kg)	T_{1i} (s)	T_{2i} (s)	$V_{1i}=L_1/T_1$ (m/s)	$V_{2i}=L_2/T_2$ (m/s)	Pi (Kg.m/s)	KE_i (J)
1								
2								
3								

After collisions								
	Cart 1	Cart2						

Trial	M_1 (Kg)	M_2 (Kg)	T_{1f} (s)	T_{2f} (s)	$V_{1f}=L_1/T_1$ (m/s)	$V_{2f}=L_2/T_2$ (m/s)	P_f (Kg.m/s)	KE_f (J)
1								
2								
3								

Discussion and Analysis:

1. Is the Linear momentum conserved?

2. Is the kinetic energy conserved?

Data:

B. Perfectly inelastic collision

L_1=…….. (m) **L_2**=…….. (m)

Before collisions											

	Cart 1	Cart 2									
Trial	M_1 (Kg)	M_2 (Kg)		T_{1i} (s)	T_{2i} (s)		$V_{1i}=L_1/T_1$ (m/s)	$V_{2i}=L_2/T_2$ (m/s)		Pi (Kg.m/s)	KE_i (J)
1											
2											
3											

After collisions											
	Cart 1	Cart 2									
Trial	M_1 (Kg)	M_2 (Kg)	M_f (Kg)	T_{1f} (s)	T_{2f} (s)	T_f	$V_{1f}=L_1/T_1$ (m/s)	$V_{2f}=L_2/T_2$ (m/s)	$V_f=L/T_f$ (m/s)	P_f (Kg.m/s)	KE_f (J)
1											
2											
3											

Data Analysis:

1. Is the Linear momentum conserved?

2. Is the kinetic energy conserved?

Conclusion:

Experiment #7: Uniform Circular Motion

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: Uniform Circular Motion

Objective

1) Allows examining the relation between mass, velocity, radius, and centripetal force.
2) To experimentally measure the magnitude of the rubber bob mass.

Experiment Duration: (*3* hours)

Apparatus:

Rubber bob, clip, stopwatch, digital balance, plastic or glass tube, string, set of weights, ruler.

Introduction:

An object moving on a circular track at a constant speed is called uniform circular motion. Although it is a constant speed, the velocity is always changing due to centripetal acceleration directed to center of the motion.

Theory:

Acceleration is the time rate of change of velocity. Since velocity is a vector, it can change in two ways: its magnitude can change and its direction can change. Either change gives rise to an acceleration. For circular motion at constant speed, the velocity is always tangential to the circular path, and therefore its direction is continuously changing even though its magnitude is constant. Therefore, the object has acceleration. It can be shown that the magnitude of the acceleration (a_c) for uniform circular motion with speed (v) in a path of radius(r) is:

$$\mathbf{a_c = v^2/r} \qquad \textbf{(1)}$$

and that the direction of the acceleration is inward toward the center of the circular path. This is illustrated in Figure 1.

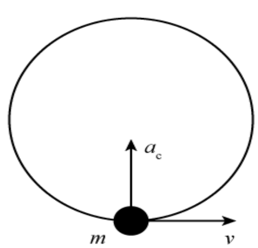


Figure (1)

Newton's second law requires that there be a net force on the object equal in magnitude to (ma_c) and in the direction of (a_c). Circular motion with speed (v) in a path of radius(r) has period (time for one revolution) (T) and frequency (revolutions/s)

$$f = 1/T \tag{2}$$

Since the object travels a distance ($2\pi r$)(the circumference of its circular path) in time (T) the speed (v) is equal to

$$V=2\pi r/T= 2\pi rf \tag{3}$$

and

$$a_c = 4\pi^2 f^{\,2} r \tag{4}$$

The setup for the experiment is shown in Figure 2. When the plastic tube is moved in a small circle above your head, the rubber bob moves around in a horizontal circle at the end of a string that passes through the tube and has a mass hanger with slotted masses suspended from its lower end. Applying

$$\Sigma F = ma \tag{5}$$

To the stationary mass hanger gives

$$F_{string} = Mg \tag{6}$$

Where F_{string} is the tension in the string and M is the sum of the masses of the mass hanger and the slotted masses that are placed on it.

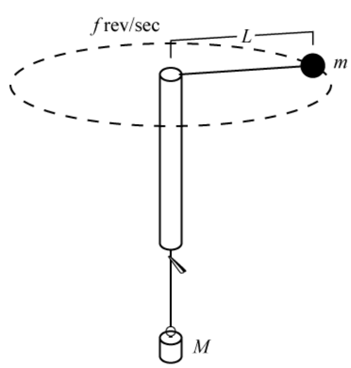


Figure 2

Experiment Set-up:

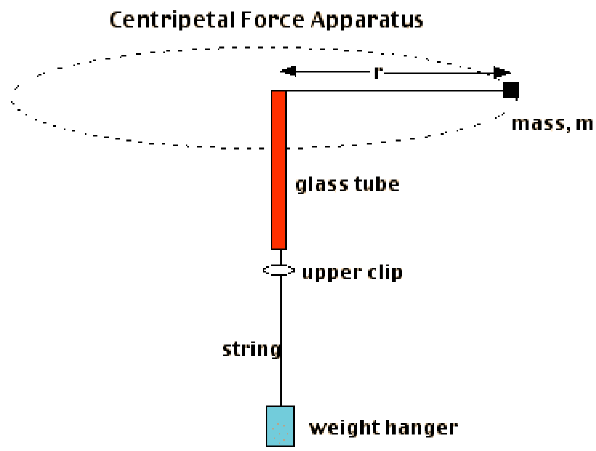


Figure (3)

Procedure:

A. Finding rubber bob mass by keeping the spinning radius constant and change the weight of the hanging mass.

1) Weight the rubber bob with a balance.
2) Fasten the rubber bob securely to the end of the string.
3) Thread the string through the tube and suspend a hanging mass to the free of the string.
4) Determine the radius (r) (the distance between the top of the tube and the middle of the rubber bob).
5) Fasten a clip to the string just below the bottom of the tube (but not touching). When you are whirling the apparatus, keep the clip just below the bottom of the tube to maintain a constant radius.
6) Rotate the rubber bob with your hand by holding the tube vertically.
7) Increase the speed gradually to adjust the rotational radius (horizontal path).

8) Now, you will measure the amount of time required for the rubber bob to make 15 revolutions with a radius (r). One member of the group will rotate the rubber bob. Another member will measure the time (using a stopwatch) and count the number of revolutions. Practice before you collect any data).

9) Repeat with different hanging masses. Record your data in Table 1.

Data :

r= ………m radius,   rubber bob mass (**m**) = ………..kg

Table (1)

Hanging mass M(Kg)	F_c=Mg (N)	Time for 15 rev.(t_{15}) (s)	Period T=t_{15}/15	Speed, v (m/s)	v^2 (m^2/s^2)	Frequency , f=1/T	f^2 ($1/s^2$)

Discussion and analysis:

1) Complete the Table 1.
2) Plot $\mathbf{F_c}$ versus $\mathbf{v^2}$.
3) Find the physical meaning and the magnitude of the slope on the graph paper.
4) Using the slop, find the magnitude of (**m**).
5) The percentage error of (**m**).
6) Write down the answers to parts (3-5) in the Results Section

Results:

B. Finding rubber bob mass by keeping the hanging mass constant, and changing the spinning radius.

Repeat the Procedure from (1-9) in part A, but by Keeping the hanging mass constant, and changing the spinning radius, and then Record your data in Table 2.

Data:

M (Hanging mass) = ……… kg, rubber bob mass (**m**) = ………..kg

Table (2)

Radius (m)	Time for 15 rev.(t_{15}) (s)	Period $T=t_{15}/15$	T^2, (s^2)	v^2, (m^2/s^2)	Frequency , f=1/T	$1/f^2$ (s^2)

Discussion and analysis:

1) Complete the table 2.
2) Plot **r** versus $\mathbf{T^2}$.
3) Find the physical meaning and the magnitude of the slope on the graph paper.
4) Using the slope, find the magnitude of (**m**).
5) The percentage error of (**m**).
6) Write down the answers to parts (3-5) in the Results Section

Results:

Conclusion:

Experiment #9: The Simple Pendulum

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ……………………………………..

Experiment Title: The Simple Pendulum

Objectives:

- Determine an experimental value of the acceleration due to gravity g.
- Investigate the dependence of the period T of a pendulum on the length L and the mass M of the bob.

Equipment Duration: 3 hours

Apparatus:

Metal sphere, string, metric ruler, stop watch, clamp and stand.

Introduction and Theory:

Simple pendulum consists of mass bob connected to a massless string with other end fixed as shown in Figure (1).

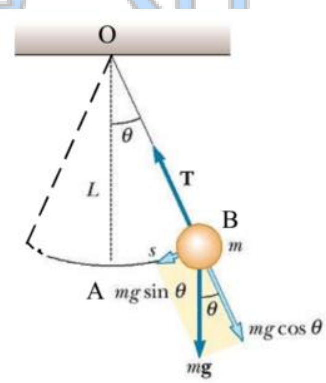


Figure (1): Simple Pendulum

The point mass moves along a circular arc, the tangential weight component represent the restoring force, it always try to bring the system to the equilibrium position, and it's opposite to the displacement direction.

$$F = -mg\sin(\theta) \quad (1)$$

The time for one complete oscillation called the periodic time (T), periodic time depends on the mass m and the constant k.

$$T = 2\pi\sqrt{\frac{M}{k}} \quad (2)$$

For small value of the angle θ, we can use the approximation sinθ = tanθ = x/L in Equation (1), which gives

$$F = \frac{-mgx}{L} \quad (3)$$

which leads to the fact that k = mg/L, putting this formula in Equation (2) gives

$$T = 2\pi\sqrt{\frac{M}{mg/l}} = 2\pi\sqrt{\frac{L}{g}} \quad (4)$$

Procedure:

Part (A): Determining an experimental value of the acceleration due to gravity g.

- Set the length of the pendulum to 1 m.
- Make an angle of 15 degrees, then release the bob, measure the time of 10 oscillations three times and find the average of the period $\bar{t}$.
- Repeat steps 1 and 2 for different lengths, tabulate your results in Table (1).

Part (B): Investigation the dependence of the period T of a pendulum on the length L and the mass M of the bob.

- Repeat the experiment for different masses with the same length.
- Fill your data in Table (2).

Data and Data Analysis:

Part (A): Determining an experimental value of the acceleration due to gravity g.

Table (1) the mass of the bob = ……………………………………….(Kg)

L (m)	Time of ( ) oscillations		$\bar{t}$(s)	τ (s)	τ^2 (s^2)	$f=\frac{1}{\tau}$(Hz)	$f^2=\frac{1}{\tau^2}$(Hz^2)
	t_1(s)	t_2(s)					

1. Calculate τ the period of one oscillation.
2. Calculate τ^2 and f^2.
3. On the graph paper, plot τ^2 versus L.
4. Calculate the slop and find g.
5. Calculate the percentage error for g.
6. From your graph determine the period of a simple pendulum 30 cm length.
7. From your graph determine the length of pendulum which has a period of 1 second.
8. Write down the answers to parts (4-7) in the Results Section below

Results:

Part (B): Investigation the dependence of the period T of a pendulum on the length L and the mass M of the bob.

Table (2):   L = ………………….. (m)

M (Kg)	Time of ( ) oscillations		$\bar{t}$(s)	τ (s)	f=$\frac{1}{\tau}$(Hz)
	t_1(s)	t_2(s)			

1. Calculate τ the period of one oscillation.
2. Calculate the frequency f. Tabulate your answers in Table 2 above
3. What is the effect of the mass on the periodic time.

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……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………

Conclusion

Experiment #10: Simple Harmonic Motion and Hooke's Law

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ………………………………………..

Experiment Title: Simple Harmonic Motion and Hooke's Law

Objectives:

- Determine the spring constant k of a spring by measuring the elongation versus applied force.
- Determine the spring constant k of a spring from measurements of the period T of oscillation.
- Investigate the dependence of the period T of oscillation of a mass on a spring on the value of the mass and on the amplitude of the motion.

Equipment Duration: 3 hours

Apparatus:

Stand base, stand supports, stand rod, multi clamp, meter tape, C-clamp with hook, extension spring, disk pointer assembly, hooked masses and rubber band, stopwatch.

Introduction and Theory:

Restoring force acts to bring a body to it's equilibrium position, it's a function of mass position. An example of restoring force is the force of spring that is proportional to the amount of elongation of the spring from it's equilibrium, directed in opposite direction of the deformation.

This relationship can be expressed as Hooke's law.

$$F_s = -Ky \qquad (1)$$

where,

F_s is the spring force in the dimension of Newton (N), y is the spring stretch or compression in the dimension of meter (m) and k is the spring constant in the dimension of (N/m). The negative sign indicates that the force is in the opposite direction of the displacement. A force described by equation (1) can produce an oscillatory motion called simple harmonic motion. The mass m connected to the end of the spring oscillates with y displacement as a function of time

$$y = A\cos(\omega t+\varphi) \qquad (2)$$

A is the amplitude of the motion and ω is the angular frequency.

$$\omega = 2\pi f = \frac{2\pi}{T} \qquad (3)$$

where, f is the frequency ant T is the periodic time. Angular frequency ω related to the spring constant according to the equation

$$\omega = \sqrt{\frac{k}{M}} \qquad (4)$$

then

$$2\pi/T = \sqrt{\frac{k}{M}} \longrightarrow T = 2\pi\sqrt{\frac{M}{k}} \qquad (5)$$

Procedure:

Part (A): Determine the spring constant k by measuring elongation versus applied force.

- Install a table rod with a rod clamp near it's top. Suspend a helical spring from the clamp with the large end up.
- Attach a 50 g weight hook with a 50 g slot mass on it to the spring. Record the initial mass of 100 g as M and the starting point x_o. The parameter m will represent the total mass on the spring.
- Place the meter stick vertically alongside the hanging mass. Measure the elongation of the spring and record it as x_1. See figure (1).

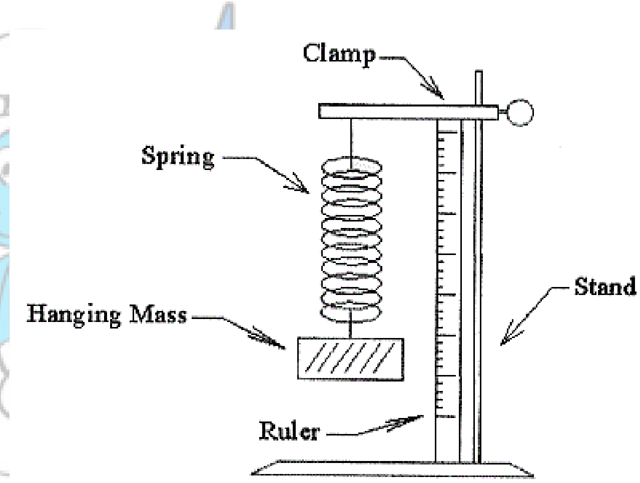


Figure (1)

- Add slot mass to the hook and record m_2.
- Repeat previous step to find x_3, x_4, x_5 and x_6.
- Record all the masses and elongations in Table (1).

Part (B): determine the spring constant k from measurements of the period T of oscillation for different values of mass.

- Add 100 g to the end of the spring, pull the spring downward 1 to 2 cm then release it, measure the time of number of oscillations for example 20 oscillations, repeat this step 3 times and find the average of oscillation, fill your data in Table (2).

Part (C): Investigate the dependence of the period T of oscillation of mass on a spring on the value of amplitude oscillation.

- Repeat the last part with increasing the amplitude and find the effect of the oscillation amplitude on the time of oscillation.

Data and Data Analysis:

Part (A):

Determination the spring constant k by measuring elongation versus applied force.

Table (1) x_0= ……………………., M= …………………….

m (g)	x (m)	$\Delta x = x - x_0$ (m)	F = mg (N)	K (N/m)
			$\bar{k}$=	

1. Plot a graph of F versus (Δx).
2. Find the slope of the best straight line? What does the slope represent?
3. Calculate the average value of the spring constant $\bar{k}$and standard deviation of the mean value Δk.
4. Write down the answers to parts (2-3) in the Results Section below

Results:

Part (B):

Determination the spring constant k of a spring from measurements of the period T of oscillation.

Table (2):

M+m (Kg)	t_1 (s)	t_2 (s)	t_3 (s)	τ (s)	τ^2 (s^2)

1. Plot τ^2 versus the load mass (M+m).
2. Find the slope of the best straight line.
3. Use the calculated slope to find k.
4. Compare your result with the value of k found in part A.
5. Write down the answers to parts (2-3) in the Results Section below

Results

Part (C):

In part C of the experiment would the period of the motion increase, decrease, or stay the same if the mass were displaced by two centimeters from equilibrium rather than one? Explain.

……………………………………………………………………………………………………
……………………………………………………………………………………………………

………
………

Conclusion

Experiment #11: Frictional forces

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ……………………………………..

Experiment Title: Frictional forces

Objectives:

Calculate the static and kinetic friction coefficients $\mu_s$and μ_k respectively.

Experiment duration: (3 hours).

Apparatus: Spring scale (balance), block of wood, incline level and masses.

Introduction:

When an object is in motion either on a surface or in a viscous medium such as air or water, there is resistance to the motion because the object interacts with its surroundings. We call such resistance a force of friction. Forces of friction are very important in our everyday lives. They allow us to walk or run and are necessary for the motion of wheeled vehicles. There are two kinds of frictional forces static (f_s) and kinetic (f_k).

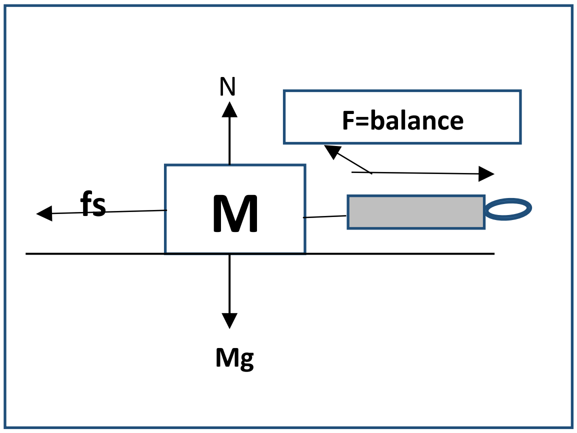
Theory:

The coefficient of static friction μ_s can be measured experimentally for an object placed on a flat surface and pulled using a known force (using a spring scale). The coefficient of static friction is related to the Normal Force N of the object on the surface, when the object just begins to slide (impending to move), at this moment the reading of the spring scale will equal Staticfriction (f_s).

$F = f_S$……………………….(1)

$N = Mg$…………………….(2)

$F = \mu_s . N$……………(3)



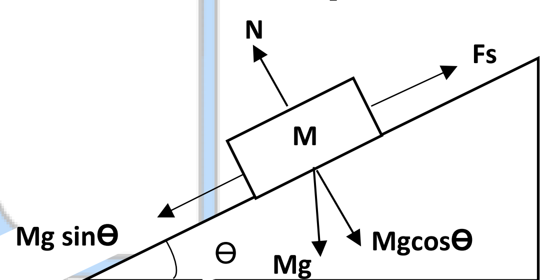
But when we pulled the object in constant speed, the acceleration (a=zero),so the spring scale reading will equal to kinetic friction (f_k).

$F=f_k$……………………….(1)

$N=Mg$……………………….(2)

$F = \mu_k . N$……………….(3)

Also we can find (μ_s) using inclined level, when the mass is about to move at an inclined plane



$f_s = Mg \sin\Theta$……………….(1)

But ($f_s = \mu_s N$)

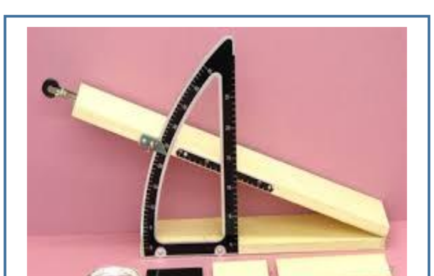
And ($N=Mg \cos\Theta$)

Then ($f_s = \mu_s Mg \cos\Theta$)…………..(2)

From eq.1 and 2 we obtain

$\mu_s = \tan \Theta$

Experiment set- up:



Procedure:

Part one: connect the spring scale to a block of wood horizontally, then pull the spring scale until the block just begins to slide, at this moment, take the reading of scale and detect the normal force on (M).Repeat the previous steps, by changing the wood block mass.

Data:

M (kg)	N (N)	f_s(N)

Note: $f_S = \mu_s \cdot N$

$\boxed{Y \quad = \quad SLOPE \quad X}$

Discussion and Analysis:

1- Fill the table above, then on graph paper plot (f_s) versus (N).

2- Write the physical meaning of slope.

3- Find the slope.

4- Determine the magnitude of (μ_S).

5- Write down the answers to parts (2-4) in the Results Section below

Results:

Part two: the steps like part one, but pull the block in constant speed, so the scale reading will equal the Kinetic friction, fill the table below, by varying the mass

Data:

M (kg)	N (N)	f_K(N)

Note: $f_k = \mu_k \, . \, N$

Y = SLOPE X

Discussion and Analysis:

1- On graph paper plot (f_k) versus (N).

2- Find the slope.

3- Determine the magnitude of (μ_k)

3-Write down the answers to parts (2-3) in the Results Section below

Results:

Part three:

Using inclined level find (μs) for different kinds of blocks.

Data:

KIND OF BLOCK	Ɵ	μs = tan Ɵ
Soft wood		
Soft iron		
Coarse wood		
Coarse iron		

1- Fill the table above by varying the blocks.

2- Take the angle of each block when it is about to slide.

Conclusion:

Experiment #12: Free fall and projectile motion

Student Name:……………………………………..

Student Number:…………………………………….

Submission Date: ……………………………………..

Experiment Title: Free fall and projectile motion

Objectives:

In this experiment, we will use the free fall of an object to determine acceleration due to gravity g. In addition to calculate each of:

1- The instantaneous velocity at some point.

2- The average velocity between two points.

3- The initial velocity (v_i) in the projectile motion.

4-The maximum height (H_{max}) at $\Theta=45^\circ$therotically and practically.

5- The horizontal rang (R) at($\Theta=45^\circ$).

Experiment duration: (3 hours).

Apparatus:

Free fall apparatus, projectile apparatus, source, connection leads, and iron balls

Introduction:

Free fall is one example of an object moving at a constant acceleration, which is the acceleration of gravity. But projectile motion consider an example in two dimension motion , where (V_{ix}) on the flying , but (V_{iy}) decrease until the projectile body reach the maximum height, then begin to increase while goes down.

Theory:

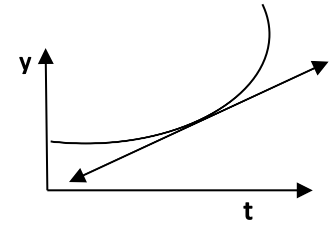
In free falling($y=v_{iy}+(1/2)gt^2$),

but (v_{iy}) =zero, so ($y=(1/2).\ g.\ t^2$).

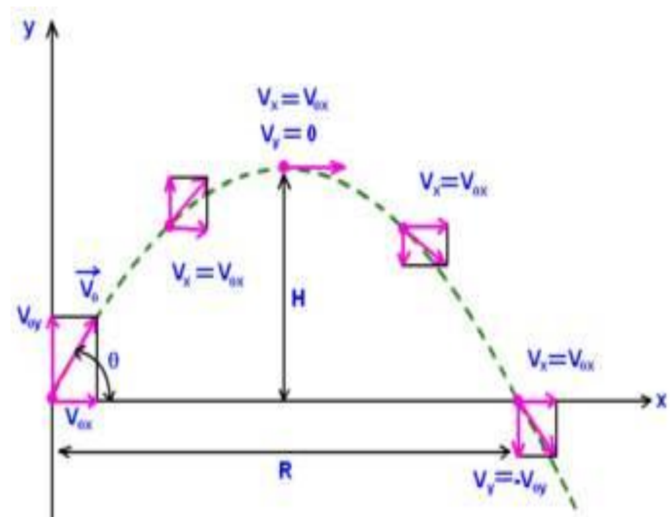
From the last equation we can plot graph between the two variables (y) and (t^2) which give straight direct proportional line. And the physical meaning of slope of this line, slope=g/2. Then you can find (g),as (g = 2.slope).

And when we plot (y) versus (t) we can find instantaneous velocity at some point

V(t)=dy/dt = The slope of tangent at any point



Also average velocity between any two points can be calculated



In the projectile motion there are two components of velocity:

($V_{ix}=V_i\cos\Theta$) in x-aixs and ($V_{iy}=V_i\sin\Theta$) in y-axis.

From equations of motion with constant acceleration

$V_{fy}=V_{iy}-gt$) …………………..(1)(

but $V_{fy}=zero$) ,(

$t_1=(V_i\sin\Theta)/g$ ………………(2)

As (t_1) is the ascension time.

So time of flight ($t=2t_1$) ,

$t=2(V_i\sin\Theta)/g$……………………(3)

Also $V^2_{fy}=V^2_{iy}-2g\,H_{max}$,………………..(4)

but $V_{fy}=zero$,

$V^2_{iy}=2gH_{max}$,…………………..(5)

Then $H_{max}=(V_i^2\sin^2\Theta)/2g$……………………(6)

The horizontal rang (R)

$R = t\,V_{ix}$,

$R = (2\,V_i \sin\Theta\, V_i \cos\Theta)/g$,…………………………(7)

But($\sin(2\Theta) = 2\sin\Theta\cos\Theta$)

Then $R = (V_i^2 \sin(2\Theta))/g$)……………………………(8)

Experiment set up:

Figure 2

Part one: Calculating the gravitational acceleration

Procedure: Use the apparatus in figure 1 to determine the height Y(m) and the time taken t(s) and tabulate your data in the next Table.

<u>Data:</u>

	t(s)	t^2 (s^2)

$$y = (g/2)\,.t^2$$

$$Y = \text{slope}\,.\,x$$

Discussion and Analysis:

1- On the graph paper plot (y) versus (t^2).

2- Write the physical meaning of the slope.

3- Find the acceleration gravity.

4- Find the percentage error in the acceleration gravity.

5- On the graph paper, plot (y) versus (t)

6- Using the last graph, find the instantaneous velocity at t= 0.3 s.

7- Using the last graph find the average velocity between

(t=0.2 s and t=0.4 s).

8- Write down the answers to parts (2-4) and parts (6-7) in the Results Section below

Results:

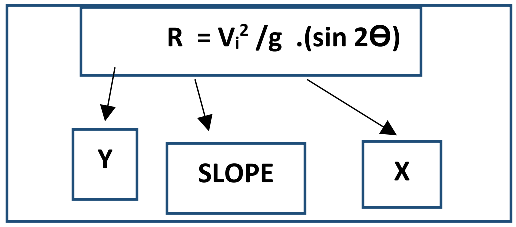
Part two: study the relationship between the projectile motions with angle:

Procedure: Use the apparatus in figure 2 to find the angle of projection and the range R.

Data:

Ө°	**R**
10	
20	
30	
40	
45	
50	

60	
70	
80	



Discussions and Data analysis:

1. On the graph paper, plot (R) versus (sin2Ө).
2. Find the slope.
3. 4Write the physical meaning of slope.
4. Find (V_i) depending on the physical meaning of slope.
5. Determine (R)at (Ө=45)mathematically and experimentally, then find the (P.E).
6. Find (H_{max}) at (Ө=45˚)
7. Calculate the time of flying.
8. Write down the answers to parts (2-7) in the Results Section below

Results:

Conclusion: